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ABSTRACT

This study examined the instructional effectiveness with which different job aid types facilitated learner achievement of different types of learning objectives and identified the degree to which low and high prior knowledge individuals profit from different job aid types. The instructional content used in the study was an instructional module on the parts and functions of the human heart. Participants (n=300) were randomly assigned to one of five treatments complemented with different job aid types, i.e., control (no job aids), cueing, association, proceduralized, and analog job aid types. After interactions with the instructional module, participants received four posttests, each measuring different educational objectives. Research findings indicated that when job aids are used following instruction: (1) they are not equally effective in facilitating learner achievement of different types of educational objectives; (2) they do not reduce learning differences between low and high prior knowledge learners; and (3) there is an insignificant interaction between job aid type and prior knowledge level. (Contains 32 references.) (MES)

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Effect of Visualization (Job Aids) in Facilitating Cognitive Development

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Abstract

Three hundred learners participated in this study which (a) examined the instructional effectiveness with which different job aid types facilitated learner achievement of different types of learning objectives and (b) identified the degree to which low and high prior knowledge individuals profit from different job aid types. The instructional content used in the study was an instructional module on the parts and functions of the human heart. Participants were randomly assigned to one of five treatments complemented with different job aid types. After interacting with the instructional module, participants received four post tests each measuring different educational objectives. Research findings indicated that when job aids are used following instruction (a) they are not equally effective in facilitating learner achievement of different types of educational objectives; (b) they do not reduce learning differences between low and high prior knowledge learners; and (c) there is an insignificant interaction between job aid type and prior knowledge level.

Introduction

The essence of appropriate instruction relies heavily on an instructional design practitioner's ability to balance instructional efficiency and effectiveness. Instructional efficiency takes into account finite resources such as time, money, and staff personnel allocated to the development of an instructional intervention while instructional effectiveness focuses on the desired performance or outcome of that intervention. To compound this situation in the corporate environment, performance demands change constantly because of the introduction of new products, services, process and technology; individuals are required to maintain current performance levels while acquiring new complex processes and skills; and management's expectations have employees performing more tasks at irregular intervals. In meeting some of these diverse demands, instructional design practitioners have relied on non-instructional interventions known as job aids (Silber, 1990). Job aids, also known as performance support tools, contain factual and procedural knowledge and are used during actual task completion (Grau, 1986; Rossett, 1991; Rothwell & Kazanas, 1994). They are effective especially when the consequence of error is high, performance is lengthy or complex, performance is changing frequently or limited budget or time exists for making an instructional intervention (Carlisle & Coulter, 1990; Finnegan, 1985).

Duncan (1985, p.1) indicates that job aids "...put more training into the programs of instruction without significantly increasing the course length, ...save time and money in training development without sacrificing student achievement, ...reduce the paperwork requirements in training development and multitude of training products...and...increase performance both initially and on a sustained basis." Finnegan (1985) proposes the following five reasons to use any job aid type: (1) to provide a performance focus, (2) to guide performance that would likely be forgotten, (3) to reduce cost and development time—as compared to training, (4) to provide flexibility of revision when task change, and (5) to be used in conjunction with training to decrease training time. Evolving rapidly, job aids have taken on a multitude of shapes, sizes and forms. Utilizing a more formal approach to the development of job aids, Rakow (1981) suggests the following job aid typology; example, cueing, association, proceduralized, and analog classification.

In recent years, the advancement of cognitive psychology has expanded the way individuals conceptualize job aids. Viewed in the past only as external mechanisms which store information and prompt memory to improve performance, job aids now have taken on additional rolls such as guiding perspectives, decisions and self evaluation (Rossett, 1991). Other individuals such as Tillman (1985) and Sleg (1988) suggest that job aids be incorporated as an instructional intervention to assist in the acquisition of skills and knowledge. Unfortunately, this paradigm shift has not occurred in the scientific community. Only a limited number of empirical research studies have been conducted using job aids. These studies have resulted in a contribution of valuable knowledge in the areas of: job aid and improved performance (Keefer, 1986; Lafleur, 1994); job aid development and implementation efforts (Ruyle, 1991; Ford, 1994); expertise transfer using knowledge based systems as job aids (Stevenson, 1990); and helpfulness of job aids in journal writing (Cole, 1993). Little research has been conducted to identify the potential educational value of job aids in the domain of knowledge acquisition. No research has been conducted to identify how prior knowledge interacts with job aids in the facilitation of knowledge acquisition. For this reason, an exploratory investigation was undertaken in this unknown area.

Statement of the Problem

Literature supports the use of job aids to decrease efficiency (finite resources) and improve effectiveness (performance). But most literature indicates that job aids are used to recall, guide knowledge and procedures previously acquired. Limited research has been conducted using job aids as an instructional intervention. It was hypothesized that the use of job aids as an instructional intervention administered directly after interacting with the instructional content would function to facilitate the acquisition and retention of the content material. The study focused on the following research questions:

- Are all types of job aids equally effective in facilitating learner achievement of different kinds of learning objectives?
- Are different types of job aids equally effective in facilitating learner achievement among learners identified as possessing high or low prior knowledge?
- Is there an interaction between learners' level of prior knowledge and type of job aid?
- Do learners identified as high and low prior knowledge levels learn equally well from identical types of job aids?

Procedure

The physiology pretest was administered to nine hundred and three participants. Participation quartiles were calculated. Participants in the first quartile were identified as the low prior knowledge group; whereas participants in the fourth quartile were identified as the high prior knowledge group. Participants in the second and third quartiles were eliminated from the study. Each participant of the prior knowledge groups was then randomly assigned to one of five treatment subgroups. Total pretest participation quartiles are displayed in Table 1.

Table 1. Total Pretest Participation Quartiles

Percentage	Quartile	Pretest Score (Number Correct)
100 %	Q4	32 - 23
75 %	Q3	22 - 21
50 %	Q2	20 - 19
25 %	Q1	18 - 03

The cut off score for the low prior knowledge group was 18. Participants in each of the treatments possessing this score or lower were classified as possessing low prior knowledge. Combining all five treatments together the low prior knowledge group had a total of 247 participants. The high prior knowledge group for each treatment contained all participants who scored 23 or above on the pretest. Combining all five treatments together the high prior knowledge group had a total of 241 participants. The descriptive statistics for the total participation group, total low prior knowledge group and total high prior knowledge group are displayed in Table 2.

Table 2. Total Participation Group, Total Low Prior Knowledge Group and Total High Prior Knowledge Group Descriptive Statistics

Statistical Computation	Total Participation Group	Total Low Prior Knowledge Group	Total High Prior Knowledge Group
N	903	247	241
Mean	20.05	15.83	25.25
Standard Deviation	4.80	2.27	2.06
Variation	23.00	5.17	4.25

After identifying the low and high prior knowledge groups of each treatment, participants with incomplete data element were eliminated. Every seventh participant was then eliminated until all treatments contained the same number of participants and the prior knowledge groups (low and high) were distributed equally. The study was conducted with a sample of N=300. The low prior knowledge group consisted of 150 participants; high prior knowledge group consisted of 150 participants. Each of the five treatments was comprised of 60 participants with 30 low prior knowledge and 30 high prior knowledge. Descriptive statistics for the sample based on low and high prior knowledge groups are shown in Table 3.

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Table 3. Descriptive Statistics for the Study Sample Based on Low and High Prior Knowledge

Statistical Computation	Low Prior Knowledge	High Prior Knowledge
N	150	150
Mean	15.62	25.20
Standard Deviation	2.54	2.07
Minimum	3	23
Maximum	18	32

Treatments

The instructional content used in both studies was a self-paced 1,800-word instructional module describing the human heart, its parts and the internal processes which occur during the systolic and diastolic phases (Dwyer, 1972; Dwyer, 1978). This content was selected because of the high reliability associated with its dependent measures and because it offers the ability to investigate different intellectual skill learning objectives (facts, concepts, rules and problem solving) that are effective and efficient performance functions of a typical work environment. The job aid typology developed by Rakow (1981) provided the skeletal format for each job aid because each job aid type identified in his typology offers advantages when used correctly. In order words, specific job aid types must be developed for specific results. To improve learner performance, it is vital that the instructional design practitioner identifies the type of information required and how the information will be utilized (Gagne, Briggs & Wager; 1972). Keeping this in mind, each of the treatments developed for the study mirror a specific intellectual skills hierarchy level. The cueing job aid possessed facts; the association job aid possessed facts and concepts; the proceduralized job aid possessed facts, concepts, and rules/procedures; and the analog job aid possessed facts, concepts, rules/procedures and problem solving information.

The same self-paced instructional module was distributed to all treatment groups. In addition to this module, all but the control group received some type of job aid and in some cases two job aids that were developed by the researchers after conducting an extensive literary search, collaborating with a content expert and determining reliability of the job aids through a pilot study. Job aids are thought to be self-sustaining, independent from training and for this reason, the researchers did not incorporate the job aids into the instructional content but placed them at the end of the instructional material to facilitate synthesization, integration and recall of the designated information. The five treatments described in Table 4 were developed specifically for the research study.

Table 4. Treatment Descriptions

Treatment Number	Group Name	Description
1	Control	Participants received the instructional module containing no job aids.
2	Cueing Job Aid	Participants received the instructional module containing two job aids designed to direct attention to the facts but did not provide step-by-step directions. The first job aid contained a heart graphic with structural parts labeled and the second job aid contained a heart graphic with labeled processes associated with blood circulation in the heart. The information in the cueing job aids provided participants with specific information they needed to discriminate between presented stimuli.
3	Association Job Aid	Participants received the instructional module containing one job aid which related unknown information to already known information in the typical format of a reference document. The job aid contained facts using a heart graphic with labeled parts numbered and concepts in the form of a definition. The numbers identified the heart parts and their respective definitions. This job aid enabled the participant to identify a stimulus as a member of a group possessing some common characteristics, even though the stimuli would differ from each other.
4	Proceduralized Job Aid	Participants received the instructional module containing one job aid describing the twelve step-by-step process of how the blood circulates through the heart. Each step had an explanation and a heart graphic. The job aid used facts, concepts and a procedure associated with the third intellectual skill level.
5	Analog Job Aid	Participants received the instructional module containing two job aids that assisted participants to conceptualize knowledge of organization, structure and relationships to solve problems and/or generate higher level concepts and values necessary to solve problems. One analog job aid presented knowledge of heart valve relationship; the other job aid provided knowledge of the circulation of blood through the heart.

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Criterion Measures

Four individual criterion measures, each measuring different learning objectives, were used as the cognitive dependent variables. The criterion measurers were administered immediately after the participants completed interacting with their respective self-paced instructional treatments. Table 5 summarizes the criterion measures. The listed descriptions are adapted from a description provided by Dwyer (1978, pp. 45-47) and illustrates the types of learning objectives that were assessed in this study. KR reliability coefficients are provided for each measure.

Table 5. Description of Criterion Measures

Criterion Measures	Description
Drawing Test	Participants recalled information found in the instructional module to construct a simple line drawing of the heart. This 20-item test evaluated the participants' ability to construct and/or reproduce content related items in their appropriate context (KR-20, 0.90).
Identification Test	Participants recalled information presented in the instructional module to identify parts and positions of an object. The test contained 20 multiple-choice questions (KR-20, 0.84).
Terminology Test	The objective of this 20-item, multiple-choice test was to evaluate the participants' understanding of facts, terms and definitions printed in the instructional module (KR-20, 0.77).
Comprehension Test	Consisting of 20 multiple-choice items, this test measured the participants' deep understanding of concepts related to the functioning of the heart (KR-20, 0.77).
Total Criterion Score	The score is the sum of adding the correct number of responses of the four criterion measures. This score provided total understanding of the instructional module (KR-20, 0.94).
Physiology Pretest	This 36-item, multiple-choice test was developed to measure the participants' prior knowledge level of human anatomy and physiology (KR-20, 0.92).

Design

The research design was a randomized post-test only design (Campbell & Stanley, 1966). Participant scores on the criterion measures (drawing, identification, terminology and comprehension tests) were identified as the dependent variable. The independent variable was job aid types (cueing, association, proceduralized and analog) and prior knowledge (low and high). The study design, a 5 X 2 crossed design, may be represented as RSIU (5 levels of job aids and 2 levels of prior knowledge). Alpha was set at the .05 level. A MANOVA was conducted to determine the overall effects where significant F ratios were obtained. Table 6 provides a summary of pretest and dependent variable descriptive statistics.

Table 6. Pretest and Dependent Variable Post Test Descriptive Statistics Correlation, Means and Standard Deviation (N=300)

	Pretest	Drawing Test	Identification Test	Terminology Test	Comprehension Test
Pretest	1.00	0.40	0.38	0.48	0.37
Drawing Test		1.00	0.80	0.63	0.61
Identification Test			1.00	0.64	0.67
Terminology Test				1.00	0.74
Comprehension Test					1.00
Mean	20.41	8.86	12.62	9.91	9.76
Stan Dev	5.33	5.31	4.61	3.68	4.18
Minimum	3	0	2	2	1
Maximum	32	20	20	20	20

Table 7 presents the mean achievement and standard deviation scores achieved by participants in each job aid by criterion measure. Where as Table 8 depicts mean achievement and standard deviation scores achieved by participants for low and high prior knowledge levels.

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Table 7. Mean Achievement and Standard Deviation Scores for Treatment

Treatment / Test Mean	Drawing Test Mean	Identification Test Mean	Terminology Test Mean	Comprehension Test Mean
Control	4.333	10.083	8.900	8.650
Cueing	9.916	13.483	9.666	9.616
Association	10.433	13.300	10.550	9.866
Proceduralized	10.033	13.516	10.933	11.150
Analog	9.066	12.716	9.516	9.533

Table 8. Mean Achievement and Standard Deviation Scores for Prior Knowledge Level

Prior Knowledge Test / Mean	Drawing Test Mean	Identification Test Mean	Terminology Test Mean	Comprehension Test Mean
High	10.920	14.253	11.546	11.266
Low	6.793	10.986	8.280	8.260

The multivariate analyses (MANOVA) indicated that for all variables an insignificant interaction existed between job aid type and prior knowledge level. However, for all variables assessed simultaneously, a main effect existed among the different job aid treatments and between the prior knowledge levels. The results of the MANOVA are displayed in Table 9.

Table 9. MANOVA Test Criteria and F Approximations for Overall Effect Using Wilks' Lambda Statistic

Variable	Value	F	Num DF	Den DF	Pr > F
Job Aid	0.767878466	4.95215	16	877.437	0.0001
Prior Knowledge	0.762896938	22.2994	4	287.000	0.0001
Job Aid*Prior Knowledge	0.931476308	1.28913	16	877.437	0.1965

Follow up analyses indicated that all four job aid treatments were significantly more affective than was the control treatment on all four of the criterion measures. However, all job aids were found to be equally effective in facilitating learner achievement on each of the criterion measures. Follow up analyses also indicated that learners in the high prior knowledge level achieved significantly higher mean achievement scores on each criterion measure than did learners in the low prior knowledge level.

Results

The multivariate analyses (MANOVA) yielded an insignificant interaction between job aid type and level of prior knowledge (Table 9). As shown in Table 9 for all variables simultaneously, a main effect existed for job aids (F=4.95) and prior knowledge (F=22.23).

Simultaneous confidence intervals using the .05 alpha level were calculated for each criterion measure to determine job aid treatment effects. On the drawing and identification measures all four job aid treatments (cueing, association, proceduralized, and analog) were found to be significantly more effective than the control in facilitating student achievement. Insignificant differences in achievement were found to exist among participant mean achievement scores on both criterion measures. On the terminology test measure, only treatments three (association) and four (proceduralized) were more effective than the control treatment in facilitating student achievement however, all job aid treatments were again found to be equally effective. On the comprehension test measure, only treatment four (proceduralized) was found to be significantly more effective than the control treatment in facilitating achievement. Insignificant differences in achievement were found to exist among the four job aid treatments.

To identify the prior knowledge treatment effects, simultaneous confidence intervals were computed using the .05 alpha level. Results indicated that low prior knowledge learners achieved significantly lower mean achievement scores on all criterion tests (drawing, identification, terminology, and comprehension) than did high prior knowledge learners.

Discussion

The findings of this study indicated that job aid treatments (T2, T3, T4, T5) were all significantly more effective in facilitating learner achievement on the drawing and identification measures than was the control

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treatment (T1) which contained only the instructional module. A possible explanation for these results may be that all job aid treatments contained a graphical picture highlighting or identifying the structural and organizational components of the heart. These graphics helped the learners organize information to facilitate acquisition, retention and subsequent retrieval of the information. Research supports the fact that long term memory visualization increases performance (Kolers & Ostry, 1974; Light, Berger & Bardales, 1975). Gagne, Walker Yekovich and Yekovich (1993) suggest that declarative knowledge (knowing that something is the case) is stored in knowledge structures in the form of a schema. Schemas are characterized as having variables, being organized hierarchically (embedded within another), and facilitating inferences. Within schemas, declarative knowledge is represented in the form of a proposition, image or linear ordering. A proposition is a basic information unit such as one idea and expresses the relationships among concepts. According to Wanner (1968) individuals do not store knowledge in words, phrases or sentences but proposition form. The control group (T1) participants receiving the instructional module containing only a narrative may have developed propositions without the assistance of job aids. However, participants who received the instructional module containing job aids may have developed propositions from the instructional narrative but also enriched the schema by adding additional declarative knowledge in the visual form of a heart graphic and linear ordering (step 1, step 2, step 3, etc.).

On the terminology measure, only treatment three (association) and four (proceduralized) were more effective than the control treatment. The explanation for this finding may be that the association job aid required additional participant interactivity with the instructional modules containing job aids. Participants looked at the graphic, identified a number related to a specific heart part, identified the heart part, located the definition of the heart part listed at the bottom of the job aid below the graphic, read the definition and related the definition back to the heart part located on the graphic. Used as an elaboration learning strategy this activity influenced the construction and integration aspects of the encoding process. Internal connections are constructed in working memory between new information and knowledge stored in long term memory. The proceduralized job aid used an organizational strategy which not only identified and related major and minor information but also assisted in selection or the paying attention to incoming information which was then transferred into working memory and construction or the building of connections between ideas contained in working memory. Both the association and proceduralized job aids provided relationship information and required additional interaction with the instructional content. Braune and Forshay (1983) and Craik and Tulving (1975) both suggest that it is only through many interactions with the task that individuals seem to develop an understanding of functional relationships contained in concepts. The cueing job aids contained factual information and required very little interaction. The complexity of the analog job aids may have produced confusion or affected the ability of the participants to discriminate relevant information for non-relevant information. Non-processed information is not locatable and retrievable during the assessment phase and therefore, negatively impacts achievement.

All job aids provided additional declarative knowledge in image form and may be the reason that all job aids did not differ significantly from one another. However, the additional interactivity of the association and proceduralized job aids was not enough to result in a significant difference between the job aid types.

High and low prior knowledge participants did not profit equally from the different job aid treatments. Participants classified as low prior knowledge had significantly lower mean identification, drawing, terminology and comprehension scores than did high prior knowledge participants. This finding is consistent with the premise that successful integration of new information occurs when it is related to existing long term information (Bransford & Franks, 1976; Clifton & Slowiaczek, 1981; Davey & Kapinus, 1985). High prior knowledge participants who received the same treatments consistently scored higher on all four criterion post tests. According to Weinstein and Mayer (1986), if an individual already possess prior knowledge of a subject, it is easier to add information, connect a new schema to make inferences and access the schema information.

All treatments contained in the study were developed as self-contained instructional books containing directions and instructional narrative and in some cases job aids. No additional assistance was rendered to the study participants. Therefore, the findings of the study may support Jonassen and Grabowski (1993) who found that high prior knowledge learners require less instructional assistance than do low prior knowledge learners and Willoughby and Wood (1994) who found that restriction of prior knowledge impacts the learners ability to integrate new information and makes instruction more difficult and increase the probability that achievement will be affected in a negative manner.

Finally, the significant lower scores for low prior knowledge participants may be the result of their inability to make inferences (Gagne, Walker Yekovich & Yekovich, 1993). Experts possess more declarative knowledge and rich domain specific relevant information than do novices and possess the ability to make correct inferences during the spread of activation in long term memory when they are unable to retrieve exact information (Weinstein & Mayer, 1986). Novices, on the other hand, are less likely to make correct inferences because of limited knowledge representation in the cognitive domain.

Conclusion

The research findings indicate that the type of paper-based job aid used with a self-paced instructional module would be based on the desired education objective. Also, if learners possess a high degree of prior knowledge, then paper-based job aids may be used with self-paced instructional content to positively effect the types of cognitive development evaluated in this study. The findings also indicate that to improve job aid effectiveness some form of interactivity such as rehearsal, elaboration, organizational or comprehension monitoring strategies be incorporated into the design of the job aids.

The study was an attempt to venture into an uncharted area of using paper-based job aids as an instructional intervention to improve learner achievement. However, the findings do not provide enough evidence to alter the current practice of using job aids as non-instructional interventions. It is vital that additional research be conducted to substantiate the findings of this study and investigate additional variables which may impact on the use of job aids as instructional interventions. Future research may include but is not limited to the following list of potential empirical research:

- Replicate the current study to substantiate findings and increase credibility.
- Replicate the study substituting Factor B, prior knowledge, with time-on-task classifications to determine if the amount of time devoted to the instructional content and job aid alters the current achievement outcomes.
- Replicate the study using a different instructional delivery medium. Use of a computer-based instructional module containing job aids may significantly impact the current achievement outcomes.
- Replicate the study using job aids containing additional forms of learning strategies.
- Replicate the study comparing the self-paced instruction with instructor-led instruction.
- Conduct a longitudinal study to assess the effect of knowledge retention when paper-based job aids are administered after a self-paced instructional module.

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